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THE ELASTOPLASTICITY BEHAVIOR OF WIRE IN INHOMOGENEOUS WOVEN METAL MESH

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Abstract. *This paper discusses the plastic behavior of wires in metal mesh for discussing the structure of woven warp and weft with their inhomogeneous and homogeneous by using finite element method (FEM). In the FEM, an isotropic plasticity is adopted as constitutive model of woven wire, but inhomogeneous between warp and weft is discussed to evaluate the mechanical characteristic of the mesh as an industrial products. Here, fundamental relation of power law hardening rule is adopted to represent the plasticity, but physical parameters of it will be controlled for the discussion of plasticity on mesh weaving. The inhomogeneous of mesh structure is one of key technology to control the product quality of metal mesh, and the mechanics of plasticity of metal mesh should be discussed to develop the product. In this report, the difference of material parameters and tension during weaving process is targeted on the discussion. Some conditions on the wires of warp and weft are examined in weaving process by FEM.*

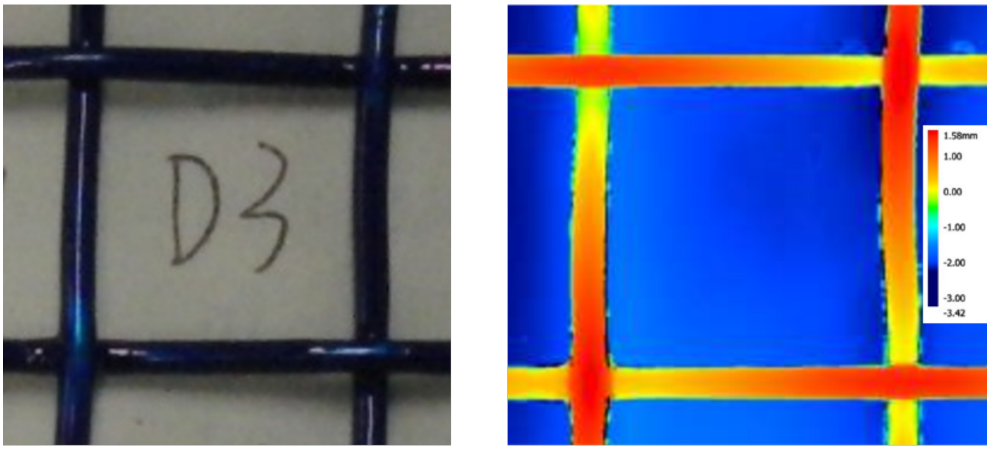
1 INTRODUCTION

Woven mesh of warp and weft wires is one of simplest materials to realize controlled structure in industrial field. Its corresponding customer needs are also clear: neatly shaped. According to the experience summarized in industrial production from previously survey, a fact was known that a metal mesh manufactured by inhomogeneous weaving tends to have a more neat appearance than by homogenous weaving method. To explore its theoretical basis of this empirical conclusion, this paper measured the shape of a metal mesh sample[1]. For comparison, some material model were designed, include one elastic model, four bi-linear elastoplastic model and one power law elastoplastic model[2, 3]. And a unit-cell corner model[4, 5] of plain woven structure was build for FEM. Using these models, simulation was performed on both homogeneous and a inhomogeneous case in finite element method.

2 EXPERIMENTAL EVALUATION

2.1 Equipment and Condition

The exact shape of plain woven metal mesh was measured by using a microscope named VR-3100 which made by KEYENCE Corporation. The specification of SUS304 mesh sample is 1.5 mm in diameter and 12.7 mm in woven pitch, which sprayed in blue for reducing optical reflection as shown in Figure 1(a). The height data of mesh sample obtained by using VR-3100 is shown in Figure 1(b). Here some data-lost occurred at wires horizontal sides, but peak position is clear and this part of wire is targeted in evaluating of deformation.



(a) (b)

Figure 1: Scope view(a) and height observation(b)

2.2 Evaluation by Digitization

The measured shapes of mesh sample was output as STEP files, STEP files was processed by using processing method in FEM mesh generation. Here, LS-PrePost®is adopted in mesh generation using data from both vertical directions, result is shown in Figure 2.

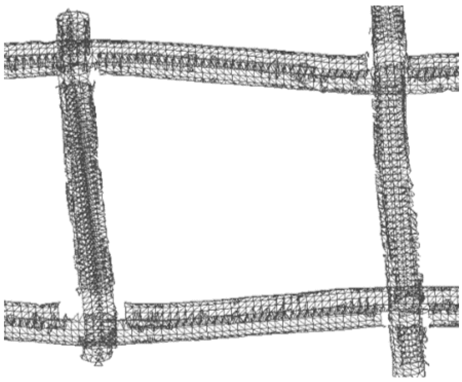


Figure 2: Digitization of experimental data

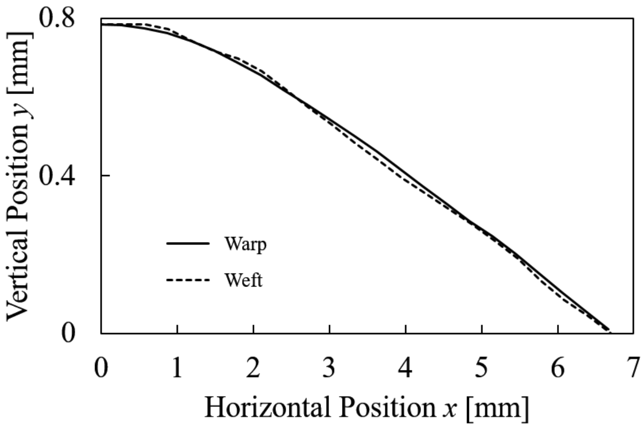


Figure 3: Profile comparison of deformed warp and weft

The digitized data of mesh shape is shown in Figure 3. Here, the deformed shape of warp and weft is duplicated to compare their situation. The difference of their deformation is not significant in this case.

3 NUMERICAL EVALUATION BY FEM

3.1 Geometry of plain woven structure

To detail the shape changes of the plain woven structure in analysis, a FEM model was performed by using corner model[4, 5] as shown in Figure 4(a). In an unit cell, wire diameter $\phi = 1.5$ mm and pitch length $p = 12.7$ mm. Diameter ϕ of warp and weft is considered as same.

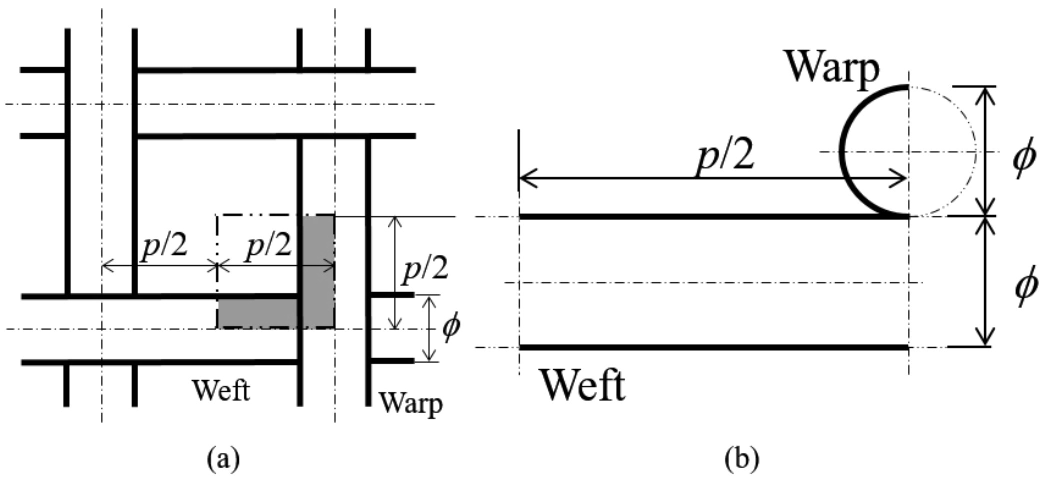


Figure 4: Unit-cell corner model of plain woven structure: top view(a) and sectional view(b)

The finite element is generated as shown in Figure 5. Here, it has 1296 elements, contain hexahedral and pentahedral elements, and its number of nodes is 1848.

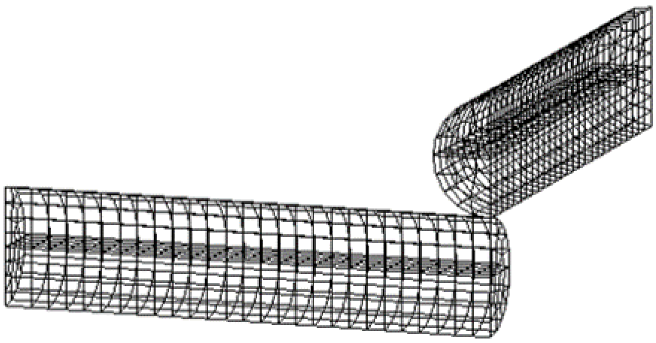


Figure 5: FE model for analysis

3.2 Representation of Plasticity by Bi-linear Constitutive Model

To obtain sufficient data for evaluate the differences in shapes of plain woven structure, some models of elastoplastic behavior are considered in this section.

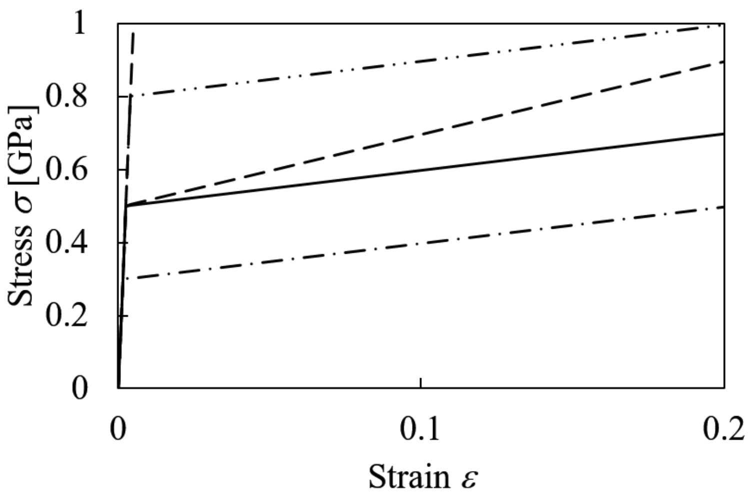
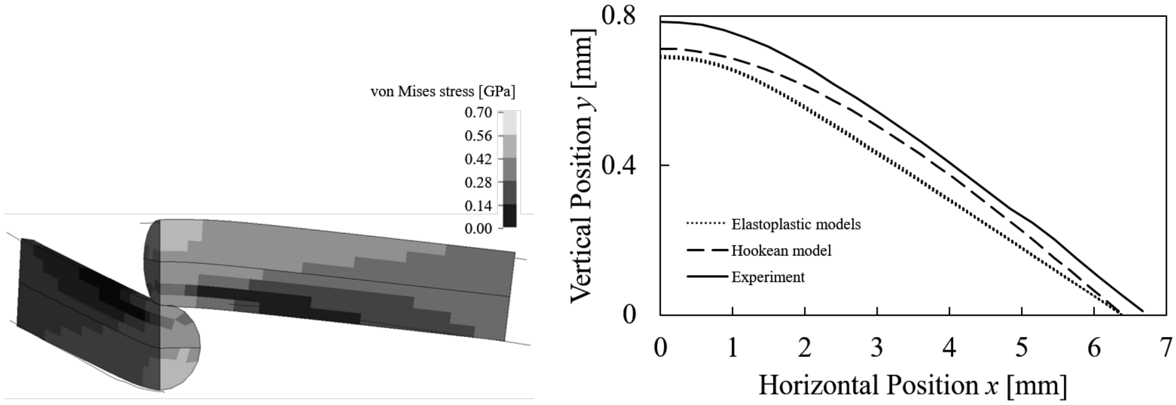


Figure 6: Modeled relationships of stress and strain

Figure 6 shows the stress-strain relationships of 1 elastic model, and 4 elastoplastic models which have same elastic modulus but different strain hardening modulus or yield stress. Three of them have same strain hardening modulus.

3.3 Results of Bi-Linear Material Model in Homogeneous Weaving

Four elastoplastic models and a elastic material model described in section 3.2 was applied in FE analysis. Its results are shown in Figure 7. Figure 7(a) shows a result of an elastoplastic model with a yield stress of 0.5 GPa and a tangent modulus of 1 GPa. In this result, the outermost region of the contact portion of warp and weft has a higher von Mises stress.



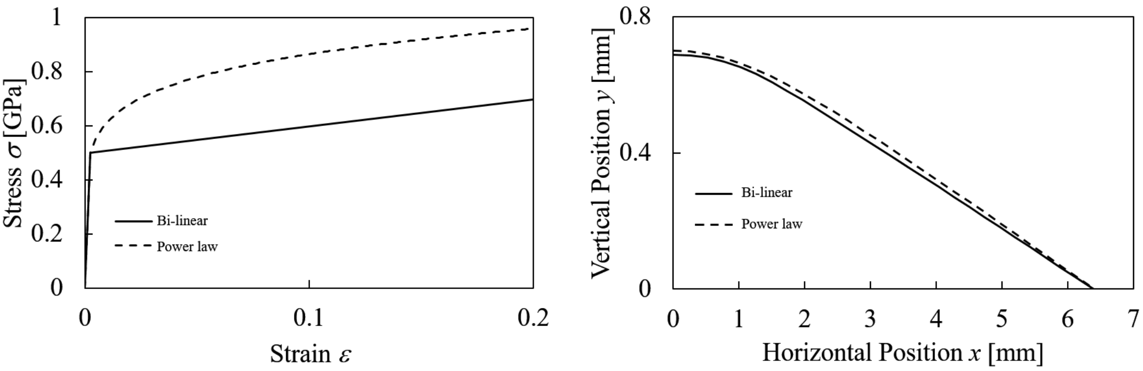
(a) (b)

Figure 7: FEA results(a) and comparison of shapes(b)

Figure 7(b) shows the outermost shape of warp in FEM result with the sample data shown in section 2.2. This result shows that: 1) shapes between 4 elastoplastic models are almost same because their tangent modulus of plastic hardening is much smaller than elastic modulus; 2) deformed profile in Hookean model has strong curve unlike the others in Figure 7(b) because plasticity causes low bending moment in weaving process.

3.4 Representation of Plasticity by Power Law Material Model

Here, an elastoplastic model that transfer to plasticity phase with power law at its yield strength is discussed to evaluate the availability of hi-linear model. The stress-strain curve of power model is shown in Figure 8(a), and results of simulation is shown in Figure 8(b).



(a) (b)

Figure 8: Modeled relationship by bi-linear and power rule (a) and its FEA results (b)

Figure 8(a) shows that power law model which tangent modulus of plastic hardening is decreasing continuously, and bi-linear model only have one tangent modulus of plastic hardening. It caused their deformed difference as shown in Figure 8(b), and it is known that the slope of power law one's curve is monotonically decreasing continuously because the tangent modulus it associated is monotonically decreasing continuously.

3.5 FEA Results of Bi-Linear Material Model in In-Homogeneous Weaving

To evaluate inhomogeneous weaving with tension will bring what visible changes, the length of warp in corner models was reduced by 0.05mm, and then applied a forced displacement to the boundary at the pitch center, make the length of warp increase 0.05mm before weaving. Its FE result is shown in Figure 9.

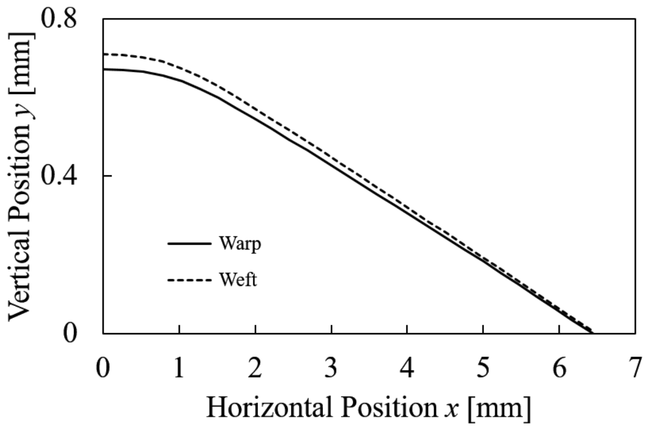


Figure 9: Comparison of Inhomogeneous Condition

The warp in Figure 9 shows less elongation in plain woven than weft. This result is considered that the application of tension caused hardening, make warp got less plastic strain on after woven procedure.

4 Conclusions

- On above, experimental measured result was simplified for comparison and further discussion.
- Results of several material FE models was compared to evaluate elastoplasticity represents in plain woven structure.
- Measured experimental data was compared with FE numerical analysis results for further research.

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